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(54) IMPROVEMENTS IN OR RELATING TO ELECTRODES

(71) I, THE SECRETARY OF STATE FOR DEFENCE, London, do hereby declare the invention for which a patent may be granted to me, and the method by which it is to be performed, to be particularly described by the following statement:

This invention relates to electrodes for monitoring bodily derived electrical signals, and more particularly to electrodes for use in electrocardiography.

It has been recognised for a considerable time that the standard "wet" electrodes used for the long term monitoring of electrocardiographic signals, exhibit particular deficiencies. The use of the depilatories and skin abrasives necessary to achieve a good ohmic contact can cause irritation, discomfort, and provide a potential source of infection; they must be reapplied several times during the monitoring period to maintain the desired contact. Furthermore sweating by a subject particularly when exercising or working during long term examination produces a marked deterioration in the standard of the results obtained.

Several different types of electrodes have been proposed to overcome the problem, however one of the best systems is the insulated or capacitive electrode first described by Richardson, Coombs and Adams (Aerosp. Med. vol 39 1968). The electrode proposed provides an aluminium conductor anodised on one side to provide an insulated layer which is placed in contact with the skin. The induced voltage provided on the conductor by bodily electric signals is amplified using a field effect transistor, by connecting the conductor to the gate of the field effect transistor connected in the source follower mode. It has been found however that such electrodes become noisy during long term subject monitoring and some fail to function at all. It has been realised that this reduced performance is due to skin

moisture ingress through the insulating layer.

It is an object of the present invention to provide an insulated or capacitive electrode for monitoring bodily derived electric signals in which the problem of moisture ingress is avoided.

According to the present invention an insulated or capacitive electrode for use in monitoring bodily derived electric signals comprises a ceramic substrate, or electrically conducting layer deposited on the substrate, and a moisture impervious electrically insulating layer deposited on the conducting layer, the electrode being adapted for use with the moisture impervious electrically insulating layer in contact with the surface of a body.

Preferably the insulating layer is glass.

Preferably the conducting layer is gold.

Preferably the substrate is substantially alumina.

Preferably an associated pattern of conductors and resistors are printed on the reverse side of the substrate.

In the diving industry, the electrode can be used to monitor the electrocardiographic signals of divers, in the present invention therefore the electrode may be placed within a screening can and the space inside the can filled with a waterproof insulating material, the only exposed part of the electrode being the insulating layer which is placed against the skin.

Preferably the screening can is gold plated.

Electrodes in accordance with the present invention may be placed directly on the skin without the use of depilatories or skin abrasives. The electrode may not only be used successfully to provide electrocardiograms, but also electromyograms, and electro-oculograms, and to monitor other bodily derived electric signals.

Manufacture of the electrode is preferably

carried out using hybrid thick film techniques.

A further problem associated with the monitoring of humanly derived electric impulses lies in earthing the subject. It has been found necessary, when using capacitive electrodes with non-floating input monitoring systems, to connect the subject to the equipment earth. However when the electrodes are used with telemetry and portable recording apparatus or other floating input systems this problem does not arise.

Variations in the interference observed with individual pairs of electrodes indicate that a solution to the earthing problem lies in careful component matching during manufacture. Therefore electrodes according to the present invention may be simultaneously manufactured as matched pairs.

The following exemplary description of the structure and manufacture of an electrode according to a preferred embodiment of the present invention will refer to the drawings accompanying the provisional specification, in which:

figure 1 is a circuit diagram of the electrode,

figure 2 is a view of the obverse side of a pair of the electrodes during manufacture, and

figure 3 is a view of the reverse sides of the electrodes during manufacture.

Referring now to figure 1, the electrode is shown placed on a subject's skin 1. The electrode arrangement comprises a capacitor formed from a pair of capacitor plates, one a metallic plate 3 the other being the skin 1, between said plates there being a dielectric layer 2. The metallic capacitor plate 3 is connected to the gate G of field effect transistor 4, connected in the source follower mode, that is with the output being taken from the source S across a resistor 6 connected to the negatively biased line, and with the drain D being connected to the positive line. A diode 7 connected between the negative line and the gate G of the transistor ensures the appearance of the correct sign of charge on the gate G. The outline of the gold-plated can in which the device is mounted is shown as 12.

The manufacture of devices is illustrated in figures 2 and 3. The hybrid thick film circuit is formed on a ceramic substrate.

A pair of substrate discs 16 are cut from 96% pure alumina and ultrasonically cleaned in toluene. The pair of substrate discs 16 are placed in a holder 15 and a capacitor plate 3 is screen printed on the obverse side 13 of each substrate disc using gold paste known under the trade name "Dupont 8237". The plates are printed on to provide a thickness of 0.0008 inches approximately. After drying for 20 minutes at 120°C the substrate discs are fired in a tunnel furnace

at 1000°C for 35 minutes.

The reverse sides 14 carry the conductor and resistor patterns. Firstly the conductors 8, 9, 10 and 11 are screen printed on the substrate discs using platinum-gold paste known under the trade name "Dupont 7553", and subsequently dried at 120°C for 20 minutes. The edge connections (not shown) linking the gold capacitor plates 3 to the printed conductors 8, to which the gates of the field effect transistors 4 will eventually be connected, are painted on by hand and the assembly fired at 950°C for 35 minutes.

As the next stage, the dielectric layers 2, formed from glass compound known as "Dupont paste 8190", are twice printed over the gold capacitor plates 3 to an approximate thickness of 40 μm , and fired at 850°C for 25 minutes cycle.

The resistors 6 are then screen printed on between conductors 9 and 11 using resistor paste known as "Dupont 1141 paste" and subsequently dried. Firing is carried out in a furnace having a maximum temperature of 760°C for 44 minutes. The values of resistors 6 are adjusted by use of an air abrasive machine in conjunction with a digital resistance meter. Encapsulation glass, known under the trade name "Dupont 8185", is printed over the resistors 6, dried, and fired for 25 minutes at 500°C.

The field effect transistors (FET's) 4 and the diodes 7 are then soldered into position on the conductor pattern, the gates G of the FET's 4 to conductors 8, the drains D to conductors 10, and the sources S to conductors 11, with diodes 7 between conductors 8 and 9. Outside connections are provided by soldering subminiature twin screened cables to conductors 9 and 10, to provide conductors 10 with positive bias and conductors 9 with negative bias.

The assembled substrate discs 16 are removed from holder 15 and placed in gold-plated screening cans 12 (shown in outline in figure 1), with the dielectric glass layers outermost. The twin screened cables are passed through a hole in the end of each can. Finally a silicon rubber layer is applied as a buffer for the electrode assembly and an epoxy casting resin is injected into the interior of each can to provide a watertight, shockproof assembly, which would be suitable for under-water work.

The electrodes are active devices but the current drain is very low, approximately 150 μA per pair, and the voltage applied is not critical, 6—15 volts being most appropriate. They can invariably be powered from associated monitoring equipment.

As previously mentioned the electrodes of the present invention would have application in the underwater field where they could possibly be built into a wet suit in order to monitor physiological functions from a

free swimming diver.

The electrodes in accordance with present invention have been found to be successful and the results of electrocardiograms recorded with this system compare favourably with those obtained using conventional "wet" electrodes.

WHAT I CLAIM IS:—

- 10 1. An insulated or capacitive electrode for use in monitoring bodily derived electric signals comprising a ceramic substrate, an electrically conducting layer deposited on the substrate, and a moisture impervious electrically insulating layer deposited on the conducting layer, the electrode being adapted for use with the moisture impervious electrically insulating layer in contact with the surface of a body.
- 20 2. An electrode according to claim 1 in which the insulating layer is glass.
3. An electrode according to claim 1 or 2 in which the conducting layer is gold.
4. An electrode according to claim 1, 2 or 3 in which the substrate is substantially alumina.
5. An electrode according to any one of claims 1 to 4 having the conducting layer and insulating layer deposited on the obverse side of the substrate and associated resistors and conductors printed on the reverse side.
- 30 6. An electrode according to claim 6 in which the reverse side of the substrate is encapsulated in glass.
7. An electrode according to any preceding claim placed within a screening can, which can is filled with waterproof insulating material, and leaving only the insulating layer exposed.
- 40 8. An electrode according to claim 7 in which the screening can is gold plated.
9. A method of manufacture of an in-

ulated or capacitive electrode for monitoring bodily derived electric signals including deposition of an electrically conducting layer on a ceramic substrate and deposition of a moisture impervious electrically insulating layer on the conducting layer using a thick film technique.

10. The method according to claim 9 in which the insulating layer is glass.
11. The method according to claim 9 or 10 in which the conducting layer is gold.
12. The method according to any one of claims 9 to 11 including manufacture of the electrodes in pairs.
13. The method according to any one of claims 9 to 12 in which the ceramic substrate is substantially alumina.
14. The method according to claim 13 including screen printing the electrode's conductor and resistor pattern on the reverse side of the substrate.
15. The method according to claim 14 including encapsulating the reverse side of the substrate with glass.
16. The method according to any preceding claim including screen printing the conductor and insulator layer.
17. An insulated or capacitive electrode for use in monitoring bodily derived electric signals substantially as hereinbefore described and with reference to the drawings accompanying the provisional specification.
18. A method of manufacture of an insulated or capacitive electrode for use in monitoring bodily derived electric signals substantially as hereinbefore described with reference to the drawings accompanying the provisional specification.

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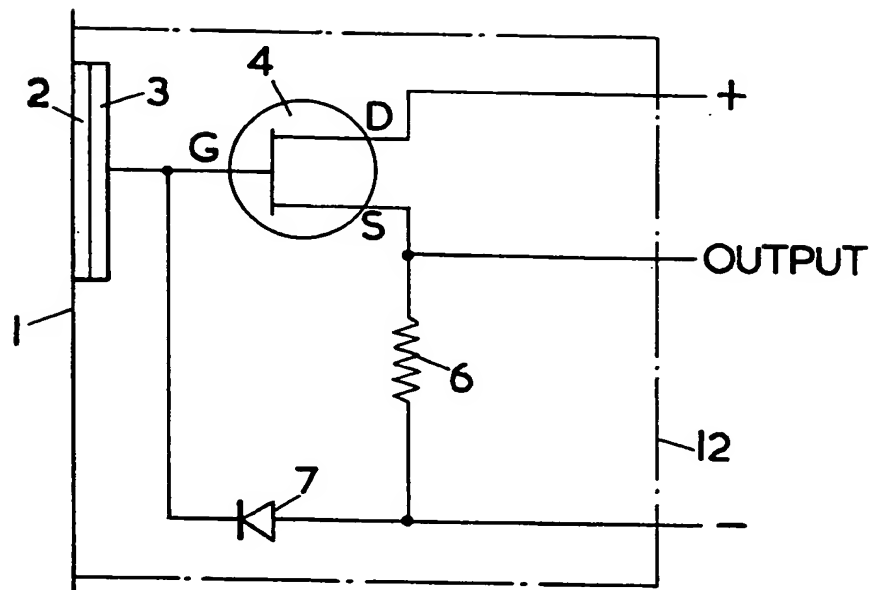


FIG. 1.

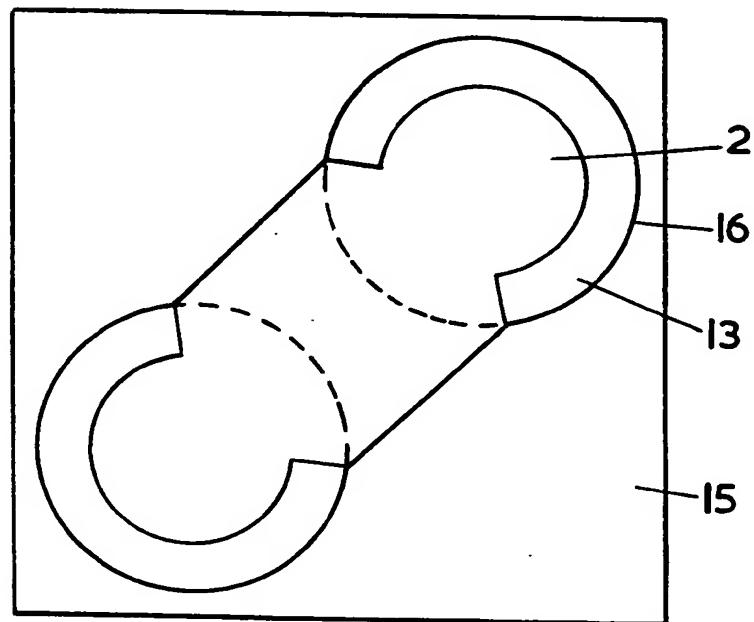


FIG. 2.

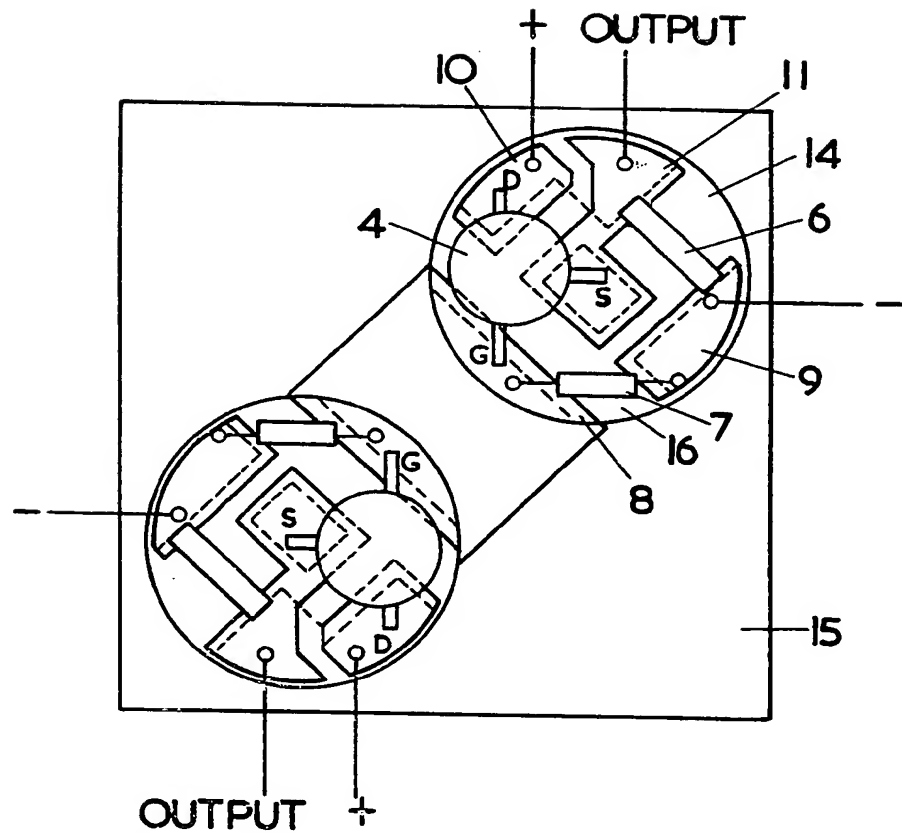


FIG. 3.

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